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Map Scale and Accuracy Standard

The goal of the Standards and Recommendations Committee is to provide recommendations and guidelines to Indiana GIS user communities to facilitate the collection, maintenance and analysis of GIS data; and, to communicate existing federal, state and local data standards. The Data Standards and Recommendation Committee will not recommend software, hardware or operating systems. Furthermore, the Data Standards and Recommendation Committee will not impose any of these recommendations and guidelines as a requirement on any GIS user community.

Introduction

Map scale, accuracy, and cost are inseparably intertwined. The accuracy an organization needs for the maps in their geographic information system (GIS) can be defined only by knowing the intended uses of the GIS. For many features such as planimetric and topographic features and digital orthophotography, the required accuracy will dictate the scale of aerial photography to be obtained. Map accuracy and aerial photography scale have a major impact on the cost of obtaining the map.

Map Scale

Map scale is defined by the U. S. Geological Survey (USGS) in its USGS Fact Sheet 038-00, April 2000, as follows:

> *"To be most useful, a map must show locations and distances accurately on a sheet of paper of convenient size. This means that all things included in the map – ground area, rivers, lakes, roads, distances between features, and so on – must be shown proportionately smaller than they really are. The proportion chosen for a particular map is its scale."*

Map scales are described as a representative fraction or a ratio, such as 1/24,000 or 1:24,000. This means that one unit on the map represents 24,000 of the same units on the ground. Sometimes scale is shown in different units, such as 1" = 2,000'. 1:24,000 scale (1" = 24,000") would be the same as 1" = 2,000'.

I get confused when people talk about larger scale and smaller scale. What does this mean?

When thinking of smaller scale or larger scale, it is best to think of scale as a fraction. As the number represented by the fraction gets larger, so does the scale. Conversely, as the denominator of the fraction gets larger, the scale gets smaller. A map at a scale of 1:100,000 (1" = 8,333') is a smaller scale map than a map at a scale of 1:24,000 (1" = 2,000'). A map at a scale of 1:2,400 (1" = 200') is a smaller scale map than a map at a scale of 1:1,200 (1" = 100').

Map scale also affects map detail. **A larger scale map can show more detail than a smaller scale map**. Another way to remember relative scale is, "larger scale, more detail; smaller scale, less detail." For example, a map at a scale of 1:24,000 (1" = 2,000') is at too small a scale to show sidewalks because a 5 foot wide sidewalk would be only 0.0025" wide on the map. This is far narrower than the narrowest line the eye can discern. A 5 foot wide sidewalk on a map at a scale of 1:600 (1" = 50'), however, would be 0.10" wide on the map, which can easily be interpreted by the eye.

My map is a digital map and I can plot it at any scale I want. Is accuracy still a function of scale?

Before computer mapping and GIS technology existed, maps were drawn by hand. Map scale was a significant contributor to the map accuracy due to the width of the pencil or pen that was used to draw the map. If a map was drawn at a scale of 1:24,000 with a pen 0.5 mm wide, each line represents a width of 12 meters. If a line represents a section line, then it is fair to say that the section line's actual location was somewhere within that 12-meter wide line representing it. If the map were drawn with the same pen at a scale of 1:1000, then the line would be only 0.5 meters wide. The accuracy of this line could be much better at a scale of 1:1,000 than at a scale of 1:24,000.

Now that many maps are drawn with computers, we can plot the maps at virtually any scale we choose. Is scale still an important factor in the accuracy of the map? The answer is, sometimes yes, sometimes no. Many digital maps are derived from aerial photography or digitized from existing paper maps. The accuracy of these digital maps is very definitely a function of the scale of the aerial photography or map. Other digital maps may show features whose locations have been determined by very accurate GPS surveys. The accuracy of these features is largely unrelated to the scale of the map. The accuracy of any paper map, however, can be affected by its scale, even if it was generated by a computer.

Map Accuracy

Map accuracy should be determined by the intended use of the map. Historically, map accuracy determined the scale at which the map would be drawn. Until recently it has been customary to specify the scale of aerial photography for digital orthophotos, planimetric features, and topographic features, and then apply the National Map Accuracy Standard or other similar standard to determine the accuracy of the map.

Recent trends, however, are to treat accuracy as a property of the map to be reported, rather than a specification for producing the map. FGDC-STD-007-1998, Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy (NSSDA), specifies testing methodology and reporting requirements for map accuracy. Section 3.1.2 states:

> *"This standard does not define threshold accuracy values. Agencies are encouraged to establish thresholds for their product specifications and applications and for contracting purposes. Ultimately, users identify acceptable accuracies for their applications. Data and map producers must determine what accuracy exists or is achievable for their data and report it according to NSSDA."*

Section 3.1.4, however, concedes:

> *"Data producers may elect to use conformance levels or accuracy thresholds in standards such as the National Map Accuracy Standards of 1947 (U.S. Bureau of the Budget, 1947) or Accuracy Standards for Large-Scale Maps [American Society for Photogrammetry and Remote Sensing (ASPRS) Specifications and Standards Committee, 1990] if they decide that these values are truly applicable for digital geospatial data."*

The remainder of the discussion will focus on traditional map accuracy standards, which are still used predominantly for specifying and reporting the accuracy of digital maps. Be aware, however, that you should consider testing and reporting the accuracy of your maps in accordance with the above referenced FGDC-STD-007-1998.

How has map accuracy traditionally been defined?

The horizontal accuracy of a map is related to the map scale. According to the United States National Map Accuracy Standards (issued by the U.S. Bureau of the Budget June 10, 1941 and revised April 26, 1943 and June 17, 1947), horizontal accuracy is defined:

> *"For maps on publication scales larger than 1:20,000, not more that 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch."*

Vertical accuracy of contour mapping is related to the contour interval, not map scale. The same publication defines vertical accuracy for contour maps as:

> *"…not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval."*

Other types of errors on maps, such as incorrect classification of features or incorrect names of streets or places are called factual errors. It is not possible to classify these errors numerically.

How do map accuracy and scale apply to a computer map in a Geographic Information System (GIS)?

Sometimes it seems strange to define accuracy in terms of map scale when applied to a computer map in a GIS system. Many of the popular GIS software packages can store the coordinates of map features to an extremely high level of precision. Do these definitions of accuracy still apply?

If the GIS map was derived from aerial photography, then these definitions *do* apply. The map scale depends on the scale of the aerial photography and the scale of the enlargements used for the planimetric mapping. A highly accurate planimetric map might be made from aerial photography flown at a scale of 1:10,800 (1" = 840'), and enlarged to a scale of 1:1,200 (1" -= 100') for planimetric mapping. Such a planimetric map that meets the United States National Map Accuracy Standards will have an accuracy of +/- 1/30 inch or +/- 3.3 feet.

What about digital orthophotos?

"Digital orthophotos combine the image characteristics of a photograph with the geometric qualities of a map." (USGS Fact Sheet 039-00, March 2000) As such, the horizontal accuracy of a digital orthophoto is the same as the accuracy of a planimetric map if they came from the same scale photography and enlargement. Digital orthophotos can be used to measure distance just like other kinds of maps.

Digital orthophotos also have a property called resolution. This is reported as a linear dimension such as one meter or 6 inches and is the size of the square on the ground represented by each pixel in the digital orthophoto. The resolution depends on the scanning aperture used in the image scanning process and is not necessarily related to the accuracy of the digital orthophoto.

What about cadastral features such as parcels, corporate boundaries, etc.?

The accuracy of these features is much more difficult, if not impossible to state. For example, if a parcel boundary described by metes and bounds is entered into your GIS by using coordinate geometry, its accuracy will be as good as the accuracy of the metes and bounds survey and the accuracy of the beginning point referenced by the survey. If parcels were originally drawn by hand over unrectified aerial photography enlargements at a scale of 1" = 200', their accuracy cannot be derived from the United States National Map Accuracy Standards because the unrectified aerial photography enlargements have a varying amount of distortion which is greater at the edges than at the center. If these parcel maps are then scanned and rubber sheeted to fit digital orthophotography or other planimetric mapping, the accuracy of the parcel layer is still difficult to state because of initial errors, errors introduced by rubber sheeting, and uncertainties in fitting the parcels to the planimetric map. The best way to state the accuracy of cadastral features is to describe the methods used in creating them.

What about features that are actually surveyed on the ground such as section corners?

These features are as accurate as the survey that determined their location. Features such as this should have their accuracy stated individually unless you are certain that all of the features in the map layer have the same accuracy.

How does map scale affect the vertical accuracy of contours?

There is disagreement in the industry about what scale aerial photography is required to produce contours that meet the United States National Map Accuracy Standards. For example, some believe 1:10,800 (1" = 840') scale aerial photography can be used to generate 2-foot contours meeting United States National Map Accuracy Standards (+/- 1 foot accuracy). Others argue that 1:7,920 (1" = 660') scale aerial photography is the smallest scale that can be used to generate 2-foot contours meeting United States National Map Accuracy Standards. References on this topic from Earth Observation Magazine include:

- http://eomonline/Common/Archives/June97/john.htm
- http://eomonline/Common/Archives/Oct97/fowler.htm
- http://eomonline/Common/Archives/Nov97/ fowler.htm
- http://eomonline/Common/Archives/July00/rick.htm

Cost

This discussion would be incomplete without mentioning the implications of scale and accuracy on cost. The relationship is very simple, as scale gets larger, accuracy gets better, and cost increases.

Recommendation

1. Decide on a map accuracy that meets your requirements and that you can afford.
2. Use a well-established standard to specify your map accuracy so there will be no confusion.
3. Verify your map accuracy by testing a small sample of points using more precise methods than used in making the map.
4. Document your map accuracy in your metadata.

There is no single map scale and accuracy that is suitable for everyone. It is vitally important, however, that you know the accuracy of your map data. The following suggestions illustrate common map scales and accuracies. If your requirements call for accuracies not listed here, that is okay. These recommendations relate scale and accuracy using the National Map Accuracy Standard. Other standards may be used if applicable.

MULTI-STATE

1:100,000 (1" = 8,333') scale quadrangle maps are commonly used for many applications, such as large regional analyses. The horizontal accuracy of maps at this scale is +/- 167 feet.

STATEWIDE AND MULTI-COUNTY
1:24,000 (1" = 2,000') scale 7-1/2 minute quadrangle maps are widely available and commonly used. For state-wide mapping, 1:24,000 scale is adequate and commonly used. In Indiana, 1:24,000 is the accepted scale for statewide framework data. The horizontal accuracy of maps at this scale is +/- 40 feet.

Maps of 1:12,000 (1" = 1,000') scale may also be common for large areas if more detail or higher accuracy is required. The horizontal accuracy of maps at this scale is +/- 33 feet (if they conform to the National Map Accuracy Standard).

COUNTY AND LOCAL
The largest practical scale for county-wide mapping is 1:1,200 (1" = 100'). The horizontal accuracy of maps at this scale is +/- 3.33 feet. Smaller scale maps such as 1:2,400 (1" = 200') or 1:4,800 (1" = 400') may also meet the requirements of county-wide mapping projects, especially if parcel mapping is the primary application and engineering applications such as drainage and transportation are not significant.

Areas smaller than county-wide areas such as small to medium sized cities and towns are sometimes mapped at a scale of 1:600 (1" = 50') for an accuracy of +/- 1.7 foot. This very large scale mapping is generally feasible only in limited areas due to its cost.

No matter what scale and accuracy you select, it is important for you to know the accuracy of your maps. This will allow you to make decisions about appropriate uses of your maps in the future. There will be opportunities to use your maps for purposes you did not consider when you first specified the scale and accuracy. If you sell or share your maps with others, they will ask you how accurate your maps are.

Examples

MULTI-STATE

STATEWIDE AND MULTI-COUNTY

COUNTY AND LOCAL

- Hamilton County Planimetric Data
  The planimetric data includes three categories: pavement edges, structure outlines, and water features (lakes, rivers, streams, ponds, etc.). This data was originally mapped at a scale of 1" = 100' in developed areas (about 2/3 of the county) and 1" = 200' in undeveloped areas (about 1/3 of the county). The accuracy standard used is Photogrammetry for Highways Committee "Reference Guide Outline: Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways." This standard requires that "Ninety (90) percent of all planimetric features which are well-defined on the photographs shall be plotted so that their position on the finished maps shall be accurate to within at least one-fortieth (1/40) of an inch of their true coordinate position, as determined by the test surveys, and none of the features tested shall be misplaced on the finished map by more than one-twentieth (1/20) of an inch from their true coordinate position."

Topographic Data

Digital Orthophotos

Parcel Data

Huntington County

Marion County

Web Links

- National Map Accuracy Standard
  http://rmmcweb.cr.usgs.gov/public/nmpstds/nmas.html

- Federal Geographic Data Committee (FGDC) Standards
  http://www.fgdc.gov/standards/standards.html

- FGDC: Geospatial Positional Accuracy Standards Part 3: National Standard for Spatial Data Accuracy
  http://www.fgdc.gov/standards/documents/proposals/progpas3.html

- FGDC: Geospatial Positional Accuracy Standards Part 1: Reporting Methodology
  http://www.fgdc.gov/standards/documents/standards/accuracy/chapter1.pdf